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A SEMANTIC THEORY BASED UPON INTERACTIVE MEANING

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ABSTRACT

When words are combined to form an expression, very often the expression means more than just the sum of the meaning of its constituents. The extra semantic information that the expression carries is the semantic interaction of its constituents. Thus, the concatenation of semantic features, words, or expressions which define the meaning of the individual constituents in an expression is not sufficient to represent the meaning of the expression. The semantic interaction of the constituents has to be accounted for. In this paper, the problem of interactive meaning existing in noun-adjunct-noun constructions is discussed. It is shown that the current semantic theory proposed by the transformationalists is, as it stands now, not adequate in handling interactive meaning. A distributional theory of meaning is briefly presented in this paper. The meaning of a word is defined by the senses it realizes in different contexts and the conceptual relations of the senses to the senses realized by the other words. Concept-classes are formed on the basis of the distribution of word senses and the contextual restrictions of each sense are specified in terms of concept-classes. The theory is applied in this paper to resolve the problem of interactive meaning in noun-adjunct-noun constructions. It is suggested that semantic interactions between words are computable. A sample of interactive meanings in noun-adjunct+noun constructions found in some restricted

data and the rules necessary to determine them are presented together with a computational procedure to determine the interactive meanings of expressions in the construction.

OUTLINE

1. SEMANTIC INTERACTION

1.1 The Problem of Interative Meaning:

When words x and y are grammatically combined, the meaning of x + y may equal the meaning of x plus the meaning of y plus something else. I shall call this "something else" the "interactive meaning" of the expression. The interactive meaning of x + y is the meaning relation of x and y. The phenomenon of interactive meaning occurs in word-combinations of most grammatical constructions. Consider the expression mink coat; it does not mean something which equals whatever mink means plus whatever coat means. It means 'coat made of mink (fur)'. The sense of 'made of' in the expression is not generally regarded as a part of the meaning of 'mink' or 'coat' out of the context. The interactive meaning which is revealed in 'made of' stands for the meaning relation between the constitutents. To understand the expression fully, we have to perceive not only the proper senses of 'mink' and 'coat', but also the interactive meaning existing in the expression.

The interactive meanings of expressions can easily be seen when we compare expressions of similar grammatical construction. Consider the pair of expressions, baby coat and mink coat; 'baby', and 'mink' are classified as noun-adjuncts by Jespersen (1917). They have the same grammatical function. However, their semantic functions are obviously

different. 'Baby' specifies the use of a coat whereas 'mink' specifies the physical composition of a coat. The interactive meanings of 'baby coat' and 'mink coat' are distinctly different since we may paraphrase them as 'coat made for babies' and 'coat made of mink (fur)' respectively. The senses of 'made for' and 'made of' in the paraphrases show the difference in their interactive meanings. This difference in interactive meanings would not be a problem if 'baby' and 'mink' always introduced the same interactive meanings when they are used as noun-adjuncts to modify head nouns. But, this is not so. In the expressions baby pen and mink pen, their interactive meanings are the same since 'baby' and 'mink' in the expressions specify the use of 'pen' and the paraphrases of the expressions, pen made for babies and pen made for minks have the same form, which generally shows the same relation existing between 'baby' and 'pen' and between 'mink' and 'pen'. Thus, we see that the interactive meaning of an expression in noun-adjunct+noun constructions cannot be determined simply by examining the sense of the modifier or that of the head noun. Rather, one has to be aware of the meaning relation between them.

When a modifier modifies different nouns, it often introduces different interactive meanings to the expressions. The interactive meanings in the following expressions are different, as shown by the different paraphrases.

(1) fish tail ..... tail of a fish

(2) fish eater ..... person who eats fish

(3) fish man ..... man who sells fish

(4) fish beam ..... beam which has the shape of a fish

(5) fish food ..... food for fish

(6) fish day ..... day in which fish are eaten

Similarly, if we hold the head noun constant and change the modifier, we can easily see the different interactive meanings existing in expressions such as the following.

(1) Dutch shoes .... shoes made by Dutch (or in a Dutch style)

(2) Alligator shoes.. shoes made of alligator (skin)

(3) baby shoes ..... shoes made for babies

(4) twenty-dollar shoes ..... shoes which cost twenty-dollars

The phenomenon of interactive meaning occurs in <u>adjective + noun</u> constructions as well. Consider the following different categories of expressions.

(1) sick room

(2) old man, good apple

(3) big eater, black day

(4) rapid writer, slow eater

The expressions in each category contain different interactive meanings. 'Sick' does not characterize 'room' in the way 'old' and 'good' characterize 'man' and 'apple'. It characterizes the persons who live in the room. 'Big' and 'black' do not semantically modify 'eater' and 'day'. Rather they characterize the objects which a person eats and the things that happened in a day respectively. Different from all the other three categories, 'rapid' and 'slow' modify the verbs that are contained in the nouns 'writer' and 'eater'. As we can see, the functions of the modifiers in each categories are different. The differences are the interactive meanings of the expressions which are shown in the following paraphrases of the expressions.

(1) room for the sick (people)

(2) man who is old, apple which is good (to eat)

(3) person who eats large quantities of (food),
day in which sad things happened

(4) person who write rapidly, person who eats slowly

The interactive meaning of an expression can be ambiguous. An expression such as "Chinese teacher' is ambiguous. It can mean (1) teacher who teaches Chinese and (2) teacher who is a Chinese corresponding to the sense of Chinese as a nationality. 'Glass container' is also ambiguous. It can mean (1) container for holding glass and (2) container which is made of glass. These two expressions are ambiguous not because the constituents of the expressions are polysemous or homonymous

but because each expression has more than one interactive meaning.

From the examples given above, we can conclude that the meaning of an expression may contain more semantic information than the sum of the meanings of its constitutents. Our understanding of an expression depends not only on our recognition of the proper sense of each word in the context of the other words in the expression, but also on our awareness of the interactive meaning(s) of the expression. Our awareness of interactive meanings is shown in our abilities to

(1) Recognize the same interactive meaning in different expressions and the different interactive meanings in the same or different expressions, and the paraphrasing relation between an expression A and an expression B which shows the interactive meaning of A .

(2) Produce paraphrases to show the sameness or differences in interactive meanings of expressions.

A semantic theory which aims to account for language users' interpretative abilities should account for the users' awareness of the interactive meanings of the expressions.

1.2 Interactive Meaning and Semantic Information

Let us now explore further what information we need to know about the individual words of an expression in order to perceive the interactive meaning of the expression. One obvious fact is that we need to know

more about the words in an expression than just the referents of the words. To know the interactive meaning of 'water bottle', we need to know not only about the referents of 'water' and 'bottle', but also that water is a liquid and can be held in a container, and bottle is a container and is a solid physical object. Our knowledge that water is a liquid and cannot be employed as a material to make a solid physical object would prevent us from interpreting 'water bottle' **as** 'bottle made of water'. We would interpret 'rubber factory' as a factory which produces rubber based on the knowledge that 'rubber' is an industrial product and a factory is a place where something is produced. One would not interpret it as 'factory made of rubber' even though it is possible for something to be made of rubber such as a 'rubber ball'. The knowledge that 'water is a liquid', 'bottle is a container for holding something', 'rubber is a product' and 'factories produce' are obviously indispensible for determining the proper interactive meanings of 'water bottle' and 'rubber factory'.

Let us further consider the different interactive meanings existing in 'milk man', 'milk bottle' and 'milk cow'. In order to determine their interactive meanings, one needs to know at least the following information:

(1) Milk is something which can be delivered.

(2) Milk is a liquid.

(3) Milk is the product of female mammals.

(4) Man delivers things as an occupation.

(5) Bottles are things for holding liquids.

(6) Cow is a female mammal.

(7) Man is not a female mammal and is not something for holding liquids.

(8) Bottles cannot deliver things and are not mammals.

(9) Cows are not employed (in this country) for delivering or holding liquids.

Knowing this information, we can determine the different interactive meanings existing in 'milk man', 'milk bottle' and 'milk cow'. We know that 'milk' in 'milk man' serves to specify the thing that a man deals with as an occupation, since (1) and (4) fit this interpretation, and furthermore, 'milk man' cannot mean 'man for holding milk' or 'man produces milk' due to (7). 'Milk man' cannot mean 'man for holding milk' or 'man produces milk' due to (7). 'Milk bottle' cannot have the same interactive meaning as 'milk man', since we know that 'bottle' cannot perform the action of delivering and 'man' is not something for holding liquid. However (2) is compatible with (5). Thus, 'milk bottle' forms a different interactive meaning which is shown in the paraphrase 'bottle for holding milk'. 'Milk bottle' cannot mean 'bottle produces milk' due to (8). The interactive meaning of 'milk cow' is different from the other two expressions, since (9) specifies that a cow cannot perform the action of delivering and is not something for holding liquid. Information in (3) and (6) are compatible. This information leads us to

the conclusion that 'milk' and 'cow' have the product-and-producer relation.

From the above examples, we know that understanding interactive meanings requires our knowledge of a lot of facts of the world. How much semantic information we have to know to describe interactive meanings adequately, and how to encode these data once they are found are problems which await answers.

1.3 Inadequacy of Transformational Theory

Let us first consider whether this problem should be solved on morphological level. Interactive meaning would not be a problem if we treated the whole expression such as 'water bottle' whose interactive meaning is different from that of 'glass bottle' as an idiom. However, if 'water bottle' is a distinct entry in the lexicon, we still need to have separate entries for 'water' and 'bottle'. If we treat 'water bottle' as an idiom, we also have to treat 'coke bottle', 'oil bottle', 'milk bottle', 'juice bottle', etc. as idoms. We can see that the lexicon would contain an enormous number of entries if this scheme were followed. However, we know that humans do not have to learn such pairs as idioms, but rather can interprete novel noun-adjunct+noun phrases on the basis of what they know about the individual components. It is this knowledge, then, which needs to be analyzed. Furthermore, we also desire in a

linguistic description, to compose a unit from smaller linguistic units. Thus, under consideration of the economy of the lexicon and of the compositional structure of language, we reject the idea of treating the expression which contains interactive meaning as an idiom.

Let us then consider whether this problem can be accounted for on the syntactical level without referring to meaning. In the recent development of transformational grammar (Chomsky, 1965), the syntactic component of a grammar contains a base component and a transformational component. The base component contains rules by which the underlying structures of the sentences are generated, and the transformational component contains rules which operate on p-markers of the base component to generate the surface structures of the sentences. The distinction between the deep structure and surface structure of a sentence is partly motivated by the fact that two sentences which have similar surface structure may have different structural descriptions on a deeper level and two sentences which have similar deep structures may have quite different surface structures. The difference between two sentences is indicated by the dissimilarity in their paraphrases. Consider Chomsky's example, as stated below; sentences (1) and (2) have the same surface structure, yet their dissimilarity on another level is indicated by the difference in the paraphrases of the sentences (3) and (4). Example (3) is not a well-formed sentence.

(1) John is eager to please.

(2) John is easy to please.

(3) It is eager to please John.

(4) It is easy to please John.

The problem of interactive meaning is a similar case. The expressions, water bottle and glass bottle, have similar surface structures and their dissimilarity is indicated by the differences in their paraphrases. To mark the difference between these two expressions on the syntactic level, we will have to assign different structural descriptions to them. Their difference may be represented by their distinct deep structures which can be generated by the base component of a transformational grammar. Transformational rules can be constructed to map the distinct deep structures to the same surface structure. For instance, we may construct the transformational rules of the following type, (1) and (2), by which the structural difference between 'water bottle' and 'glass bottle' can be distinguished. Here I assume that 'bottle for holding water' and 'bottle made of glass' are the deep structures of 'water bottle' and 'glass bottle' respectively.

(1) x_1 + for + holding + x_2 → x_2 + x_1

(2) x_1 + made of + x_2 → x_2 + x_1

The transformational rules represented by the examples above involve

the deletion of 'for', 'holding' or 'made of' and the rearrangement of x_1 and x_2. These rules are different from the transformational rules represented by (a) and (b) in that they contain meaning-bearing words such as 'made of' and 'for holding'. But let us assume for the moment that 'made of' and 'for holding' are grammatical formatives as 'be', 'an', 'by' and 'n't' in (a) and (b).

(a) passive transformation

$$x_1+x_2+x_3+x_4+x_5 \rightarrow x_2+be+en+x_3+by+x_1+x_5$$

(b) negative transformation

$$x_1+x_2+x_3 \rightarrow x_1+x_2+n't+x_3$$

The structures on the left-hand side of (1) and (2) are the deep structures which can be generated by the base component of a transformational grammar. The structural descriptions of 'water bottle' and 'glass bottle' are represented by two distinct derivations of the base component and their transformational history. The base component will generate preterminal strings that consist of grammatical formatives and complex symbols. Then the lexical rule inserts lexical items to the preterminal strings to get the terminal strings such as (1) and (2) shown below. It is at the stage of the insertion of lexical items that semantic information must be referenced. For a transformational grammar to handle interactive meaning, it must be able to generate terminal strings like (3) and (4) shown below.

(1) bottle for holding water.

(2) bottle made of glass.

(3) coat for holding mink.

(4) coat made of babies

How can a syntactic component determine whether a pair of nouns will fit in the contexts '_____for holding_____' and '_____made of_____' without making reference to the meanings relations among the nouns and the contexts? To determine whether a pair of nouns fit in a context, we should not check only on whether the syntactical category or feature of one noun can go with the syntactical category or feature of the other, because the pair of nouns may be compatible yet they may not occur in a certain context. For example, 'mink' and 'coat' are compatible since we have the expression 'mink coat' or 'coat made of mink (fur)', yet they cannot occur in the context '_____for holding_____'. For a base component of a transformational grammar to generate the terminal string 'bottle for holding water' and reject the string 'coat for holding mink', it has to refer to the meaning relations of 'bottle', 'water' and 'for holding', and to the meaning relations of 'coat', 'mink' and 'for holding'.

The above examples show that the selection of lexical items to form the terminal strings of the base component requires references to the meaning of the lexical items and their meaning relation to the contexts. If we want to reserve syntax as a notion which does not deal with meaning, the semantic component would be the proper component for handling

interactive meaning.

The semantic theory proposed by transformationalists offers no solution to the problem. In the early paper entitled "The Structure of a Semantic Theory", Katz and Fodor attempted to draw a domain for a semantic theory and classified the problems of interactive meaning as one which a semantic theory should not deal with. The examples (1) "Our store sells alligator shoes" (2) "Our store sells horse shoes" were used to show that our interpretation of 'horse shoes' and 'alligator shoes' are based on our knowledge of the world. How do Katz and Fodor distinguish between linguistic information and non-linguistic information? They defined one sense of 'bachelor' by the path of semantic marker human, male, young, ..., and in the lexical entry of 'hit' they specified subject: (physical object) as the selection restrictions. What are these semantic markers and selection restrictions? Are not these information specifying such facts of the world as 'a bachelor is a human', 'a bachelor is a male', 'higher animal can hit physical object', 'physical object can hit physical object', etc? Katz and Fodor's distinction of linguistic facts and non-linguistic facts or knowledge of the world is not at all justified.

Having ruled out the problem of semantic interaction as one which falls outside of the domain of a semantic theory, Katz and Fodor proposed the amalgamation of semantic paths when lexical items are grammatically combined. According to the projection rule for the amalgamation of the semantic markers of a modifier and a head, the meaning of a noun phrase

is represented by the total sum of the semantic features of the modifier and the head noun. That this is totally erroneous can be seen from a consideration of adjective + noun constructions. According to the projection rule, the semantic markers of an adjective and a noun in the construction are amalgamated, disregarding the different functions that an adjective can have in relation to the noun it modifies. The semantic features of 'black' are added to the features of 'day' in the noun phrase black day just as the features of 'red' are added to the features of 'flower' in the noun phrase red flower. No distinction is made on the different functions that 'red' and 'black' serve. 'Red' serves to characterize the 'flower' itself in the sense of 'the flower is red' while 'black' serves to characterize not the 'day' but the things that happened in the day. Similarly, in the noun-adjunct+noun construction, 'coke bottle' does not mean whatever is coke plus whatever is a bottle. Suppose 'liquid' and 'drinkable' are semantic markers of 'coke'; then they can certainly not appear in the semantic path of the phrase coke bottle. Otherwise, the sentence I drink a coke bottle may become semantically nondeviant. Naturally there is another problem of handling the contradictory features 'liquid' and 'solid' in the path for 'coke bottle' since 'solid' is a semantic feature for 'bottle'. All these examples show that simple amalgamation of semantic features fails to mark the interactive meaning of an expression and thus cannot distinguish the different semantic functions of words in different expressions.

Since the publication of Katz and Fodor's article, the semantic theory has gone through many substantial changes and expansions in the later publications put forth by Katz and his co-author. The expansion which is relevant to our present discussion is the introduction of the evaluation semantic markers into the lexical readings of nouns. An evaluation semantic marker is of the form '(eval = ( ))', which is distinguished from other markers in the semantic theory. The inner parentheses indicate a semantic marker which specifies the aspect of the meaning of the noun serving as the standard of evaluation. Evaluating semantic markers are subcategorized to mark the differences in the type of evaluation. For example, the marker ($Evan_{use}$ = ( )) in the reading for 'knife' marks the fact that knife is evaluated in terms of its use. The marker ($Eval_{duty}$ = ( )) in the reading for 'mother' marks the fact that someone who is evaluated as a mother is judged in terms of the performance of duty. (For detailed description of the evaluation semantic marker, see Katz 1966 pp. 283-317.) It was proposed that if the lexical reading for the adjective 'good' contains a marker, ($Eval_{x}$ = ( )), where 'x' is a variable over the subscripts 'use', 'duty', etc., as its selection restriction, different type of evaluations can be specified when 'good' is used to modify nouns. For example, 'good knife' would have the marker ($Eval_{use}$ = ( )) in its reading and 'good mother' would have the marker ($Eval_{duty}$ = ( )) in its reading. Thus, the different functions of 'good' can be represented by the different evaluation markers selected.

This idea would seem applicable to the resolution of the problem of interactive meaning. To mark the different functions of 'mink' when it is used as a modifier of 'coat' and 'pen', we may introduce markers of the type similar to the evaluation semantic markers, which may take the form (Eval 1 = ( )). If we assign the marker (Eval 1_{use} = ( )) to the lexical reading for 'pen' and (Eval $1_{composition}$ = ( )) to 'coat' and specify the marker (Eval 1_{x} = ( )) as the selection restriction of 'mink', different interative meanings of 'mink pen' and 'mink coat' can be represented by (Eval 1_{use} = ( )) and (Eval $1_{composition}$ = ( )). Thus 'mink' specifies the use of pen in 'mink pen' and the composition of coat in 'mink coat'.

However, this approach would run into difficulty when we attempted to use the same markers to identify the interactive meaning of 'baby coat' and 'baby pen'. If we specify the marker (Eval 1_{x} = ( )) as the selection restriction of 'baby', (Eval 1_{use} = ( )) would be selected as a marker for the reading of 'baby pen'. However, (Eval $1_{composition}$ = ( )) would erroneously be selected as a marker for the reading of 'baby coat'. This forces us to assign a different marker, let us name it (Eval 2_{x} = ( )), as a selection restriction of 'baby' and specify the marker (Eval 2_{use} = ( )) in the lexical reading for both 'coat' and 'pen'. Thus, the interactive meaning of 'baby coat' and 'baby pen' is represented by the marker (Eval 2_{use} = ( )) while the interactive meanings of 'mink coat' and 'mink pen' by the markers (Eval $1_{composition}$ = ( )) and (Eval 1_{use} = ( )) respectively. Unfortunately, this does not take care of

the problem. It fails to show that 'mink pen' has the same interactive meaning as 'baby pen' and 'baby coat' since (Eval 1_{use} = ( )) and (Eval 2_{use} = ( )) are distinct markers. Thus, we may conclude that the use of evaluation semantic markers gives no solution to the problem we have illustrated.

Moreover, this semantic theory is not able to mark the ambiguity of the expression which has more than one possible interactive meaning. Consider the expression glass container. It has the following two readings: (1) container made of glass, (2) container for holding glass. A fluent speaker of English can mark the ambiguity of the expression. But, according to the projection rule proposed in the Katz theory (the amalgamation of markers) 'glass container' will have only one reading no matter what markers or structure of markers are introduced in the lexical readings of the senses 'glass' and 'container'. If 'glass container' has only one reading, it is not ambiguous according to the definition of ambiguity stated in the theory. Thus in this respect, the theory fails to achieve one of the goals set by the theory, i.e., to account for language users' abilities to determine semantic ambiguities.

I shall, in the following section, give a brief description of a distributional theory of meaning and show in section 3 how the theory can be applied to resolve the problem of interactive meaning in noun-adjunct+noun constructions.

2. A DISTRIBUTIONAL THEORY OF MEANING

2.1 Senses as Minimal Meaning Units

The idea that two morphemes have the same meaning if they have the same distributions has long been suggested by linguists such as Joos (1950), Harris (1951, 1954) and Francis (1958). However, no semantic theory based on distributions of linguistic elements has been established despite the fact that experiments on the measurement of meaning distances (Rubenstein and Goodenough (1965)) and on the semantic classification based on word distributions (Harper (1965), Spark Jones (1965, 1967)) seem to indicate the applicability of the distributional approach to meaning. There seems to be no doubt that words differing in meaning have different distributions if we take into consideration the use of the words in the whole language. However, the distributional approach appears to run into a problem, if the analysis of word meanings is, for practical purposes, based only on the occurrences of words in some set texts. In some texts, words having the same distributions may not mean the same. For example, 'flower' and 'rose' may have the same distributions in a text yet have different meanings. Conversely, words having different distributions in the texts may have the same meaning. For example, the similarity in meaning of 'gentle' and 'gentleness', 'important' and 'importance' may not be determinedon the basis of their distributions. Based on the word distri-

butions in limited texts, distributional analysis of word meanings often fails to distinguish the different senses realized by a word and to identify the senses realized by different words of the same or different syntactical categories. Consequently, the semantic classifications of words often fail in representing the true semantic properties of words.

For a distributional approach to work, it seems necessary first to identify the senses of words in the contexts that the words can occur in and then to determine the conceptual relations of the senses on the basis of the distributions of the words which realize them. A single word may realize a multitude of senses, and many words which belong to the same (or different) syntactical categories may realize the same sense in a given context. Words used as the realizations of senses are arbitrary, conventional and different from language to language. But senses are universal to all people under similar social and cultural backgrounds. We should regard the senses rather than their symbolic representations such as morphemes or words as the minimal meaningful units. Just as phonemes in phonology and morphemes in morphology, senses are basic units in semantics.

Analysis of the senses of words can be done by examining the uses of the words in those contexts within which the words are semantically related. In a sentence, the semantic relations of a word with the other words can be described in terms of dependency relations. For example, we may say that a determiner or an adjective depends on the noun it modifies since

we observe that the sense it realizes can often be determined on the basis of the meaning of the noun modified by it. It realizes different senses when it modifies different nouns. For the same reason, we may say that a transitive verb in a sentence depends on its subject and its object; a preposition depends on its head and its object; and an adverb depends on the verb it modifies, etc. Thus, in analyzing the senses of a word, we may take a large sample of words with which the word forms dependency relations in sentences, and use them as contexts to contrast the different senses of the word. To achieve this, we would naturally have to rely on language users abilities to determine whether or not particular words have the same meaning in a given context. The senses found by this heuristic approach would be close to completeness since the words we select as contexts are semantically related to the words in actual sentences and thus would be more likely to provide semantic information for contrasting the different senses of the word.

Procedures, similar to the type used by linguists to find phonemes and morphemes and the methods used in experimental psychology to determine the senses of words, can be applied to determine the senses of words. We shall not pursue this problem here. A sense finding procedure and a small-scale experiment based on the methods of scaling and association are reported in Su (1968).

2.2 Concept-Classes

Distinct word senses may be conceptually related to one another. A language user can often determine whether one pair of senses is conceptually closer than the other pair. This indicates that a language user cannot only identify the various senses realized by words in different contexts, but also form conceptual groupings of senses. To find the conceptual groupings or concept-classes that people in a speech community form, I propose that we examine how the words are actually used by the people of the community i.e., that we examine the distributions of the words in actual discourse. Since senses of words can be determined in sentences, we can talk about the distributions of senses as well as of words. Senses which can fit in the same linguistic contexts often have some conceptual properties in common. Those words which can be the subject of one sense of 'eat' have something in common since the referents of these word senses can all perform the action of eating. Similarly, those senses which can be the object of 'eat' have something in common since the referents of the word senses are something which can be eaten. Those senses which can be modified by one sense of 'colorful' can be grouped under one concept-class since they must contain the same conceptual property which can be characterized as being colorful. Similarly, those modifiers which can modify the same noun may be grouped under one concept-class. We do not know exactly what is the conceptual property that a group of senses have in common in order to be used in the same linguistic context. In fact, we do not have

to be concerned about finding the conceptual properties of senses. What we are interested to know is what are the senses which may legitimately fit into a given context. The distribution of senses, in fact, reflects the conceptual properties of senses. The information as to whether a sense of a word can legitimately combine with a sense of another word is obtainable. Any native speaker of a language may serve as an informant. Thus, corresponding to each sense of a word in a language, we can form at least one concept-class which contains all and only those senses of words which can legitimately combine with the sense. A concept-class, therefore, is a set of senses of words which can legitimately occur in a particular context.

The concept-classes found in this way are not disjoint. One concept-class may contain a sub-set or all of the word senses of the other concept-class or classes. For example, some of the senses of words which can be the subject of 'eat$_1$' may also be the subject of 'sing$_1$'. (The subscript 1 indicates the most frequently used sense of the word). Thus the concept-class of the latter can be marked as the sub-class of the former. The concept-class corresponding to 'eat$_1$' may itself be a subclass of the concept-class containing senses of words which can be the object of 'see$_1$'. By checking the set relation of the concept-classes, we can draw the hierarchical structure among concept-classes.

Based on the senses of the words and their distributional properties in a language, we can construct a system of conceptual tree structures. The procedure is as follows:

1) We may start to form the concept-classes of the senses of words in one syntactical category, for example, the category noun, by listing all the senses of words in the category noun which can be legitimately combined with each senses of words in other syntactical categories such as verb or adjective. Corresponding to each sense of a verb, we list all the senses of nouns which can be the subject of the verb, and, in separate section, list the senses of nouns which can be the object of the verb. Similarly, corresponding to each sense of an adjective, we list all the senses of nouns which can be modified by the adjective. Let us work out a simple example. Suppose we want to find the concept-classes formed by the following senses of words:

Sense List: faith, beauty, boy, dog, play, lose, jump
lift, simple, good, big, real

L_1

lose ← boy, dog
lose → faith, beauty, dog, boy
lift → boy, dog
lift ← boy, dog
play ← boy, dog
simple : faith
good : boy, dog, faith
big : boy, dog
real : boy, dog, faith, beauty

Senses on the left hand side are the contexts in which senses on the right hand side can legitimately occur. The arrow → indicates that the senses of nouns on the right hand side can be the object of the senses of verb on the left hand side. The arrow ← indicates that the senses of nouns can be the subject of the senses of verb. Each sense list on the right hand side is a concept-class for the category noun. However, many concept-classes are redundant. We may mark down only the distinct concept-classes formed.

By the same process, we may list the senses of verbs or of adjectives which can be the verb or the modifier of each noun.

L_2

faith ← lose

boy → lose, lift, jump, play

dog → lose, lift, jump, play

beauty ← lose

boy ← lose, lift

dog ← lose, lift

faith : simple, good, real

boy : good, big, real

dog : good, big, real

beauty : real

The sense lists on the right hand side are the concept-classes formed. We may mark down only the distinct concept-classes and ignore the

redundant ones. This process can be used for forming concept-classes of senses of words in any syntactical category. The concept-classes of the senses of words in one syntactical category are formed according to the relationships between the words and the words in other syntactical categories with which the words can be grammatically combined. For example, to form the concept-classes of adverbs, we may use verbs and adjectives as contexts and form the lists like those in L_1 and L_2 with the senses of verbs and of adjectives on the left hand side and the senses of adverbs on the right hand side.

2) Having obtained the distinct concept-classes in the first step of analysis, the next task is to draw the relations among the concept-classes formed. We want to build up structures showing the hierarchical relations among concept-classes. This can be done by checking the number of overlapping senses in the concept-classes to form class-and-subclass relations. In our previous example, there are four distinct concept-classes formed in the lists in L_1. They have the conceptual structure relation as shown in Figure 1.

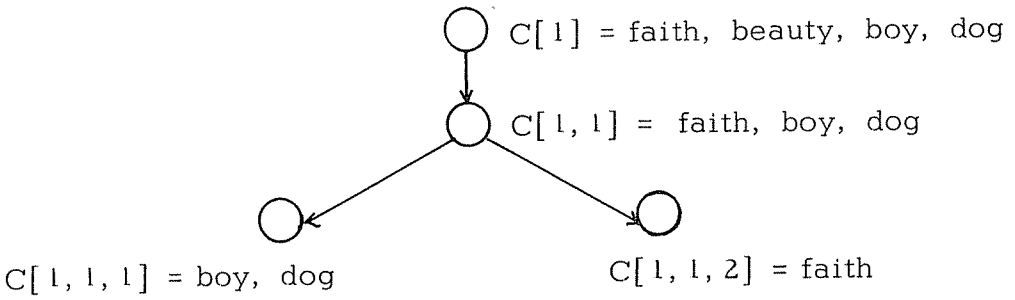

Figure 1

The verbs as well as the adjectives in the example form three distinct concept-classes. Their relation can be shown by the conceptual structures in Figure 2.

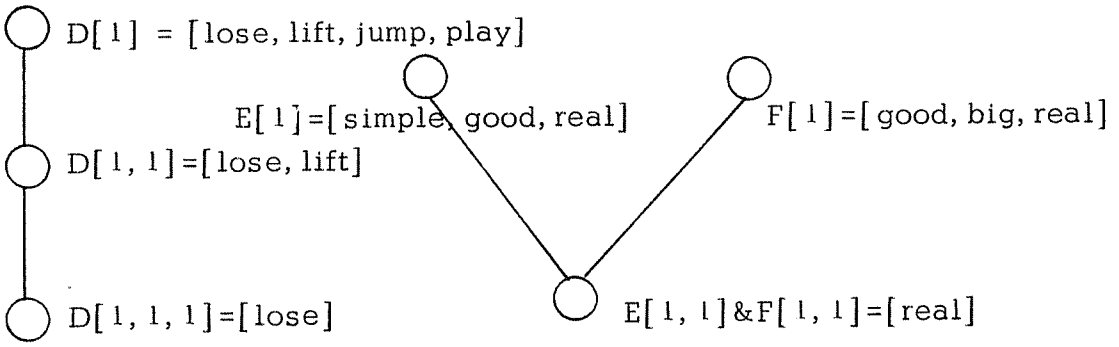

Figure 2

The concept-classes formed by the above procedure are conjoint. A sense of a word may belong to several concept-classes. However, among the concept-classes, some may be of higher level of abstraction than others. The hierarchical structure of the concept-classes can be traced. We may define the concept-class of the lowest level of abstraction (CLLA) to be the one which does not dominate other concept-class(es) containing all senses of the concept-class. If a sense of a word belongs to a concept-class A, it automatically belongs to all the concept-classes which are the nodes leading to A in the conceptual structure. Thus, if we

specify in the lexical entry that a sense belongs to the concept-class(es) of the lowest level of abstraction, we have implicitly specified that the sense also belongs to the concept-classes of higher levels. The sense of the words in the previous example belong to the concept-classes as shown below:

faith	: C[1, 1, 2]	lose	: D[1, 1, 1]	real	: E[1, 1] and F[1, 1]
boy	: C[1, 1, 1]	lift	: D[1, 1]	simple	: E[1]
dog	: C[1, 1, 1]	jump	: D[1]	good	: E(1] and F[1]
beauty	: C[1]	play	: D[1]	big	: F[1]

Since 'faith' belongs to C[1, 1, 2], it also belongs to C[1, 1] and C[1] which dominate C[1, 1, 2].

The number of concept-classes in the system depends upon the number of word senses realized by the words in a discourse and the distributions of these senses. It is forseeably quite large. However, we know it is finite and not larger than the number of the senses, since redundant concept-classes will occur when we use each senses as a context to form a concept-class. An illustration for forming the system of conceptual structures is given in Su (1968). In the example, three sub-systems which correspond to the syntactical Noun, Adjective and Verb are formed on the basis of the distributional relations of some 250 word senses. One hundred and sixty one classes are formed. The number is less than the number of senses used. Since the forming of each concept-class is

based on the fact that language users have determined that some senses can legitimately occur in a certain context and others cannot, the concept-class formed can be used in a semantic theory for marking such distinction in their distributions.

As illustrated in the above procedure, the distributions of a sense are its distributional relations with all the syntactically related senses in a discourse rather than its occurrences in some existing texts. The concept-classes of nouns formed by using adjectives as contexts alone would be equivalent to the semantic fields in Osgoods (1957). However, in forming concept-classes of nouns, we take into consideration the distributions of the senses realized by nouns in the contexts of not only adjectives but verbs and prepositions as well.

Since concept-classes are formed according to the grammatical relation of words, we will obtain a separate sub-system of conceptual structures for the senses of words in each syntactical category. The structures described form a lattice. However, they can be represented in the form of a tree. We can visualize that the top node of each sub-system of conceptual tree structures is the name of that syntactical category, such as noun, verb or adjective. The top node then branches to the various concept-classes formed on the basis of the senses of words in that syntactical category. Thus, the syntactical categories are themselves concept-classes of the higher level of abstraction in the sub-systems of conceptual tree structures. The sub-systems are all dominated

by the top node of the system of conceptual structure which contains all senses of the words in the language. Thus, the first two levels of concept-classes in the system may look like the following (Figure 3):

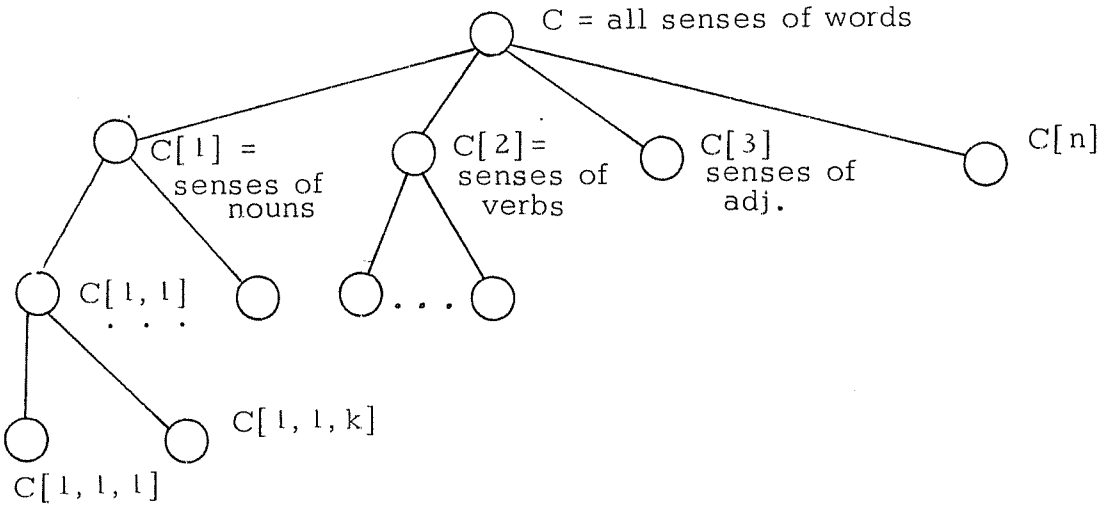

Figure 3

The senses of words in the concept-classes represented by the high-level nodes have a more abstract conceptual property than those in the concept-classes represented by the low-level nodes. Suppose, in Figure 3, C[1,1] contains all the senses of words which can be the object of 'see_1' and C[1,1,1] contains all senses of the words which can be the subject of '$live_1$'. Among all senses in C[1], only some of them have the conceptual property of being visible. Thus, C[1,1] represents a more precise or less abstract conceptual property than C[1]. Similarly,

C[1, 1, 1], specifies a more specific conceptual property than C[1, 1]. For example, if 'man$_1$' is in both C[1, 1] and C[1, 1, 1], on the level of C[1, 1], we know that 'man$_1$' has the conceptual property of something being visible just as all other senses in C[1, 1]. But, on the level of C[1, 1, 1], we not only know the property of something being visible but also the property of something being alive. If we trace a branch of conceptual tree structure downward, the deeper we get the more precise conceptual properties we find about the senses in the concept-classes. Thus, we can visualize the whole system of concept-classes as a spectrum. At one end of the spectrum, we see concept-classes which are formed on the basis of general and abstract conceptual properties of senses, and at the other end, we see concept-classes which are formed on the basis of specific and less abstract conceptual properties of senses. One end represents the general conception of senses of words and the other end the specific facts of the world.

The system of concept-classes at the abstract end can be considered to be the syntactical categories. For example, F[1, 1] in Figure 3, containing all senses of words which can be the object of 'see' is similar to the syntactical category Noun$_{concrete}$, and C[1, 1, 1] containing all senses of words which are names of living things is similar to the syntactical category Noun$_{animate}$. One may argue that C[1, 1] and C[1, 1, 1] are concept-classes containing senses which have conceptual properties in

common, and the concept properties of senses of words are parts of the meaning of words. One may also argue that $Noun_{concrete}$ and $Noun_{animate}$ containing the words which realize the senses in $C[1,1]$ and $C[1,1,1]$ are syntactical categories which are formed according to whether words can fit into the slots (see _____) and (_____live) and thus without making reference to "meaning". To favor the former argument over the latter is as arbitrary as to favor the latter over the former. The reason is as follows. The senses of words of any language form a system of concept-classes which are related to one another in a hierarchical structure. What is generally regarded as syntax is actually the part of grammar which deals with the relations of the abstract concept-classes in the system, such as $C[1]$, $C[2]$ ... $C[n]$ in Figure 3, and what is generally regarded as semantics is actually the part of grammar which deals with the relations of those concept-classes which are on the lower levels in the system. Going from the top levels to the bottom levels, we have concept-classes with gradual decrease in degrees of abstraction. If we select one level on the tree structure and call the concept-classes above the leve as syntactical categories and those concept-classes starting from the level down as part of semantics, we have made an arbitrary choice since there are no significant differences in degree of abstraction between those concept-classes immediately above the level and those on the dividing level. This may explain why linguists have difficulties in determining the boundary between syntax and semantics.

For the convenience of discussing the semantic problems in this report, I have been assuming and shall continue to assume that there is a syntactic component which operates on some of the abstract concept-classes as syntactical categories. Based on these syntactical categories and the relations among them, the concept-classes for a semantic theory are formed.

2.3 Lexicon Structure

A lexicon is one component of a semantic theory. It contains the syntactic and semantic information about words in the language. Each distinct word takes a distinct entry, and each entry contains the distinct senses of the word. Associated with each sense of a word is the following semantic information in the lexicon: 1) the sense number, 2) its sign, 3) its frequency count, 4) the concept-class(es), to which the sense belongs, 5) contextual restrictions specifying, in terms of concept-classes, the senses of words in other syntactic categories which can be legitimately combined with the word with respect to the particular sense. The examples shown in Figure 4 illustrate the structure of a lexicon. The names of the concept-classes are suggestive only. They can be identified by symbols which stand for their positions in the system of conceptual tree structures. The frequency counts of senses of a word are given to show how we can represent the relative frequency of the use of these senses by assigning different weights to them. They can be determined on the basis of the

entry	syntactical category	sense number	sign	frequency count	concept-class(es)	contextual restrictions
the	det.	11		5	/determiner/	modifier:/detl/
big	adj.	21	+	7	/size/	modifier:/determiner/ /greatness/...
		22	+	5	/importance/	modifier:/determiner/..
immediately	adv.	31		4	/instance/	predicate:/departure/, /deed/,/resolve/..
boy	n	41	+	5	/youngling/	modifier:/determiner/,/size/, /virtue/,/youth/...
solve	v	51		7	/resolve/	subject:/animal/,/human/, /evidence/... object:/inquiry/,/secret/, /difficulty/...
		52		5	/dissolve/	subject: object:/paper/,/substance/..
in	prep.	61		5	/position/	head:/human/,/animal/, /construction/... object:/school/,/world/...
		62		5	/enclosure/	head:/human/,/animal/, /material/,/substance/... object:/construction/, /inclosure/...

Figure 4

number of contexts in which the senses are realized. There is no relation between the frequency counts of one entry and that of the other. Positive signs are arbitrarily assigned to those senses which obviously have their opposite senses. For example, one sense of 'big', large in physical size, is marked as 21, and -21 would stand for one sense of 'small' as small in physical size. For those senses whose opposite senses are not commonly recognized by the language users, no sign would be assigned. The senses listed in each entry are by no means complete. However, associated with any other senses, the same type of semantic information could be stored.

The contextual restrictions of each sense of an entry are structured according to the grammatical relations between the entry and words of other syntactical categories. In the lexical entry of a determiner, the contextual restriction specify, in terms of concept-class, the determiners which can occur at the left side of the entry in utterances. For example, /det_1/ may contain 'all', 'only', 'both' and 'just' which may occur before 'the' in utterances. In the lexical entry of an adjective, the contextual restrictions specify, in terms of concept-class, the determiners and adjectives which can occur at the left side of the entry. For example, 'the', 'a', 'any', etc. in /determiner/and 'great' in /greatness/ may occur before 'big' with respect to sense 21. Thus, the orders of adjectives which may modify the same head noun are specified in the lexicon. In the lexical entry of an adverb, the contextual restrictions of each sense of the entry specify, in terms of concept-class, the verbs and the adjec-

tives which can be modified by the entry with respect to that sense. The contextual restrictions of each sense of a noun specify, in terms of concept-classes, the determiners and the adjectives which may modify the noun. Similarly, the contextual restrictions of each sense of a verb specify, in terms of concept-class, the nouns which can be the subject of the verb and also the nouns which can be the object of the verb. For an intransitive verb, the contextual restrictions would contain only the concept-classes of nouns which can be the subject of the verb. In the lexical entry of a preposition the contextual restrictions of each sense of the entry specify, in terms of concept-classes, the senses of words of other syntactical categories (noun, verb or adjective) which can occur as head or object of the entry.

From the above examples, we see that the general principle of structuring the contextual restrictions in the lexicon is as follows. Corresponding to each sense of an entry, we specify, in terms of concept-classes, the senses of the words which can be grammatically combined with the entry. Since there is a sub-system of concept-classes corresponding to each syntactical category, the contextual restrictions of each sense will contain concept-classes belonging to different sub-systems. We may arrange these concept-classes according to the different sub-systems to which they belong.

A change in the number of syntactical categories will effect the structure of the lexicon. Suppose the syntactical components of a grammar

distinguishes two categories of nouns: N_1 (animate nouns) and N_2 (inanimate nouns). The concept-class $C/1/$ in Figure 3 will accordingly be subdivided into two concept-classes $C_1/1/$ and $C_2/1/$. $C_1/1/$ may contain the senses of the words in the syntactical category N_1 and $C_2/1/$ the sense of the words in N_2. They will be immediately dominated by the top node C and become the top nodes of two separate sub-systems of concept-classes. The contextual restrictions of a verb will now contain concept-classes of both sub-systems as the subject or object of the verb. Thus, the structure of a semantic lexicon depends on the syntactical categories of a language and the syntactical relations among the categories. It is in the structure of the lexicon that syntax joins semantics.

Since the lexicon is supplemented by the system of conceptual structures, the contextual restrictions of the senses can be specified in the lexicon in terms of CLLA's (concept-classes of lowest level of abstraction). The compatibility of two senses can be determined by checking the structural realtions between the concept-class(es) to which the senses belong and the contextual restrictions of the senses. The sense selection rule is as follows:

Rule: Suppose a and b are two distinct entries and $s_1 s_2 \ldots s_n$ are the distinct senses of a, $t_1 t_2 \ldots t_m$ are the senses of b where $m, n \geq 1$. Let $C(s_i)$ and $C(t_j)$ be the sets containing CLLA's to which s_i and t_j belong respectively, and $R(s_i)$ and $R(t_j)$ be the sets containing

contextual restrictions of s_i and t_j respectively where $1 \leq i \leq n$ and $1 \leq j \leq m$. When a and b are grammatically combined, s_k and t_h, for some k ($1 \leq k \leq n$) and h ($1 \leq h \leq m$), are the proper senses of a and b respectively if either $R(s_k)$ contains a concept-class which is equal to or dominates a concept-class in $C(t_h)$, or $R(t_h)$ contains a concept-class which is equal to or dominates a concept-class in $C(s_k)$.

The sense selection rule accounts only for the local contexts of words in a sentence. By this rule, we can select the proper sense or senses of other syntactically related words. A word combination is anomalous if no proper sense can be selected for any word in the word combination.

3. THE RESOLUTION OF INTERACTIVE MEANING

3.1 Contextual Restrictions and Facts of the World

The contextual restrictions in the lexical entries specify facts of the world. For instance, as shown in Figure 4, we have specified that 'big' in /size/, 'good' in /virtue/, 'young' in /youth/ can be the modifiers of 'boy'. In the entry for 'solve', we have specified such facts as 'man solves the problem', 'boy solves the puzzle', 'evidence solved the problem'. In the entry of 'in' (sense 61) we have specified such facts as 'boy in school', 'man in the world', 'house in the city', and in the entry of 'in' (sense 62), we have specified such facts as 'match in box', 'man in building', 'cloth in drawer'. The difference between the contextual restrictions of the proposed type and the listing of simple facts of the world is that the contextual restrictions are represented in terms of concept-classes in a hierarchical structure and thus the conceptual relation between words (which form the statements of facts) can be traced. Thus, the contextual restrictions contain more semantic information than a listing of facts of the world. The semantic information represented by the contextual restrictions are necessary for the resolution of the problem of interactive meaning.

To illustrate this, let us recall the previous example of the different interactive meanings in 'milk man', 'milk cow' and 'milk bottle' and the facts of the world needed to distinguish them. If we specify in the lexicon

the concept-classes containing senses which can be the subject of 'produce$_1$' and also the concept-classes containing senses which can be the object of 'produce$_1$' we have specified who can produce what. "Cow$_1$' would be grouped with other senses of words to form a concept-class which is one of the contextual restrictions of the subject of 'produce$_1$', and 'milk$_1$' would be grouped with other senses of words to from a concept-class which is one of the contextual restrictions of the object of 'produce$_1$'. Thus, the semantic information that a cow is a kind of animal which produces and milk is a kind of product can be represented by the fact that 'cow$_1$' and 'milk$_1$' can fit into the slot (_____produces$_1$_____).

The knowledge we have about 'milk' as being something which is often delivered and about 'man' as being able to perform the action of delivering are shown in our use of the words 'man', 'milk' and 'deliver'. Since we may say 'man delivers milk', 'man$_1$' and 'milk$_1$' would be grouped with other senses of words to form two concept-classes which are in the contextual restrictions of 'deliver$_1$' ('milk$_1$', 'man$_1$' and 'deliver$_1$' are taken as the common senses of 'milk', 'man' and 'deliver' respectively). Thus, the contextual restrictions specified in the entry of 'deliver$_1$' in fact contain some particular semantic information about man and milk. Similarly, the contextual restrictions in the entry of 'for holding' represent some particular facts about milk and bottle. Contextual restrictions in the lexicon not only serve to resolve ambiguities and to detect semantic anomalies but also specify the semantic information necessary to account for the problem of interactive meaning.

3.2 Understanding of Interactive Meanings

In a previous section, we have stated that our awareness or understanding of interactive meanings is shown in our abilities 1) to recognize the same interactive meaning in different expressions and different interactive meanings in the same (or different) expressions and 2) to produce paraphrases to show the sameness or difference in interactive meanings of expressions. To program a computer to perform these tasks, we need to construct rules to transform expressions into paraphrases which show their interactive meanings. Let us assume that we have paraphrasing rules of the form $Q_1 \longleftrightarrow Q_2$ where Q_1 and Q_2 are two readings (sequences of proper senses) of two expressions. Q_2 shows the interactive meaning of Q_1 and vice versa. The two-way arrow indicates that Q_1 can be transformed into Q_2 and Q_2 into Q_1. Let us further assume that for each interactive meaning, we can construct a paraphrasing rule of the type described. Thus, each paraphrasing rule is said to be applicable to an expression, if the reading of the expression matches with one side of the rule and the application of the rule results in a semantically well-formed reading which is on the other side of the rule. The interactive meaning(s) of an expression can be represented by the paraphrasing rule(s) applicable to the expression.

With the above assumptions, the task of recognizing differences of interactive meanings between any two expressions amounts to finding the

same paraphrasing rule or two different rules applicable to the expressions. If one single paraphrasing rule is applicable to both expressions, the expressions have the same interactive meaning, otherwise they have different interactive meanings. Two expressions are paraphrases of each other if the same paraphrasing rule is applicable to both expressions and the readings of the expressions match with two sides of the paraphrasing rule. The task of producing paraphrases to show the interactive meanings of expressions amounts to applying the paraphrasing rules applicable to the expressions. Thus, the problem of interactive meaning can be handled by a computer, if paraphrasing rules of the type described can be constructed for each interactive meaning existing in the language. But before we can attempt to construct the paraphrasing rules, we must first find what interactive meanings are recognized by the language users. In the following two sections, a sample of interactive meanings found in noun-adjunct+noun constructions and their corresponding paraphrasing rules are given.

3.3 Interactive Meanings in Noun-adjunct+noun Constructions

In this report, only the interactive meanings in the noun-adjunct+noun construction will be dealt with. One way of finding the interactive meanings in the noun-adjunct+noun construction is to collect the expressions which are composed of a noun-adjunct and a noun, and group them into categories according to the meaning relations of their constituents. For example,

'rubber ball', 'paper plate' and 'iron bar' may be grouped together into one category since the noun-adjunct in each expression serves to specify the physical composition of the head noun. The meaning relation (interactive meaning) between the noun-adjunct and the head noun in the three expressions are the same. Naturally, the decision as to which expression belongs to which category has to base on the language users' intuition of the language. Through language users' ratings of the sameness in the interactive meaning of expressions or their ratings of the sameness in the paraphrases of the expressions, we can attempt to achieve the categorization of the collected data.

The data used in the present study are obtained from entries in the Encyclopedia of Britannica and the Oxford English Dictionary, from articles in Scientific America, U.S. News and World Report, Life Magazine, McCalls Magazine, and from daily conversations. The collected data were analyzed and grouped into categories which represent distinct interactive meanings, according to the judgment of a small number of native speakers.

The following is a sample of the categories obtained from the analysis. Each expression in the selected category contains a noun-adjunct and an inanimate noun. The category names shown specify the functions of the noun-adjuncts in the construction. They serve no purpose other than to suggest the interactive meanings represented by the categories of expressions.

Category	Date
1) Object available	food store, book store, steel factory, drug store, car factory, cocktail bar, coal mine, gas station, relay station, instrument company, tobacco counter, refreshment bar, mink farm, fish pond, fish hatchery, horse ranch, rice paddy, flower shop, fish market, jewelry store, toy shop, train station, bus depot
2) Time of appearance	evening star, morning train, October issue, spring flower
3) Value	penny newspaper, dollar bill, twenty-dollar shoes
4) Style	Dutch shoes, Chinese food, German beer, Japanese transistor, cowboy pants
5) Resemblance	baby face, team work, fish beam, fish dance (a type of dance which resemblances the dance of fish), horse face
6) Producer	Dutch shoes, Chinese food, German beer, Japanese transistor, mink nest, mink den, Eskimo blanket
7) Material	mink coat, alligator shoes, stone well, beef stew, paper plate, leather jacket, iron bar, rubber ball, atomic bomb, marble palace, brick wall, fruit juice, fish ball, ivory tower, fish cake, fish glue, veal casserole, brass reindeer, plastic divider, nylon cord, steel cable, nylon floor, plastic cover, metal spring, corn meal, fruit salad, corn whiskey, plastic pants, bamboo curtain, wool sweater, cotton dress, plastic toy, paper bag, lace dress, leather handbag, rubber glove, grass skirt, glass container, silver spoon, gold ring, tin can, iron stove, leather notebook, glass jug, paper carton, paper furniture, paper flower, rubber band, fish sticks, wool blanket.

8)	Use	marriage license, entrance permit, baby coat, winter jacket, book case, golf ball, movie camera, balance wheel, horse shoes, water bottle, traffic rule, dog food, book shelf, pool table, communication network, communication satellite, demonstration model, weather radar, space vehicle, billiard table, buffet table, racing car, racing horse, anti-aircraft weapons, troop plane, war equipment, battle plane, gas spray, gas mask, ammunition ship, delivery vehicle, computer card, draft card, field equipment, fish knife, fish scale, fish basket, fish hook, fish boat (boat for carrying fish), baby pen, mink pen, fish bait, water tower, road map, fishing rod, troop supply, face mask, baby spoon, baby bonnet, bathing suit, swimming trunk, swimming pool, eyebrow pencil, automobile tire, nail polish, cooky jar, floor wax, medicine cabinet, bicycle rack, glove compartment,
9)	User	police weapon, police car, marine bunker, army radar
10)	Possessor	school dormitory, government property, state zoo, enemy missile, marine radar, police weapon, marine bunker, government facility, enemy troop, government money, university house, Vietnamese culture, human problem, government force, American force, police force
11)	Location (Spatial location of activity and object)	Wisconsin cheese, car radio, space ship, underground bunker, air target, ground target, bank account, world market, city school, city slum, city park, campus couple, city smog, street theater, library books, kitchen utensil, church parlor.
12)	Sets in which object is contained	bottle cap, finger tip, human brain, book cover, table legs, computer circuit, ear canal, eardrum membrane, chair legs, camel hide, ax head, banana peel, pig ear, horse tail, fish egg, flower head, toe nail, apple seed, pot handle.
13)	Sets contained in object	diamond ring, diamond brooch, five-story house, rice soup, array radar, multi-room house

14)	Specification	birth certificate, guest list, grocery list, sage word, street name, orange slice, college campus
15)	Activity	administration office, football field, service station, football stadium, opera house, music school, tennis court, communication station, sales department, research agency, radio division, training base, concert hall, radio station
16)	Subject concerned	capabilities report, progress report, intelligence report, riot film, peace film, history book, world report, seed business, research work, research project
17)	Spatial location of activity	hospital work, bank robbery, house work, school administration, air traffic, space administration, air power, world trade, inland navigation, street battle, jungle war, lake cruise, street fight, public presentation
18)	Cause	fish poisoning, car accident, food poisoning
19)	Human involved in activities	Vietnamese war, American war, North Korean aggression, red offensive, American strategy, Vietnamese position, Chinese domination, Soviet system, negro riot, student riot, student turmoil, student demonstration, communist threat, student uprising, student revolt
20)	Object used in activities	cocktail party, dinner party, tea party, football game, dinner dance, tank warfare, nuclear warfare, nuclear war, fashion show, art show
21)	Time of activities	night patrol, winter migration, spring hunt, Friday meeting, Sunday service
22)	Occasion	wedding reception, commencement ceremony
23)	Incidence	blowout protection
24)	Object of action	water cooler, money changer, grenade launcher, flame thrower, troop carrier, water heater, plate lifter, fingernail clipper, egg beater, cake mixer, cooky cutter, pencil sharpener, bottle warmer, can opener

The categories shown above should not be taken as final. With some ingenuity, a person can certainly find some subtle distinctions of the interactive meaning of the expressions in a category and can divide the category into subcategories, each representing a distinct interactive meaning. Take category (11) for example. We may further sub-divide the category into 1) 'location of immovable object' which would contain such expressions as 'church parlor', 'underground bunker', etc. 2) 'origin of movable object' which could contain such expressions as 'Wisconsin cheese', 'library books', etc. 3) 'location of the intended use of movable object' which would contain such expression as 'kitchen utensil'.

These variations in the selection of interactive meanings are unavoidable. However, we are not concerned about each individual's distinction of interactive meanings. Rather, we are interested in finding the interactive meanings recognized by most people of the speech community. If more extensive analysis of the data shows that two distinct interactive meanings are recognized by most language users in the expressions in category 11, the category can be sub-divided into finer categories. The number of interactive meanings recognized by the language users would determine the number of paraphrasing rules required to account for them. Such changes, however, would not affect the function of the rules and the procedures for handling the interactive meanings to be presented in the following sections.

The possible number of interactive meanings existing in <u>noun-adjunct+ noun</u> constructions is obviously finite since we have a finite number of nouns

in the language and thus a finite number of expressions composed of a noun-adjunct and a noun. Judging from the proportion of the data collected and the number of interactive meanings found in the tentative analysis, the number of interactive meanings existing in noun-adjunct+noun constructions is relatively small. The categories, each of which corresponds to a distinct interactive meaning, contain a large number of expressions frequently seen in general discourse. If the data are taken from a more specific or limited discourse, the number of interactive meanings would be smaller and certainly manageable by a modern computer.

3.4 Paraphrasing Rules

Corresponding to the categories, each of which represents a distinct interactive meaning, listed in the preceding section, we may construct paraphrasing rules of the following types.

PR1: $x + y \longleftrightarrow y + \left\{\begin{matrix} \text{where}_1 \\ \text{in}_3\text{+which}_1 \\ \vdots \end{matrix}\right\} + x + \text{to be}_1 + \left\{\begin{matrix} \text{sold}_1 \\ \text{produced}_1 \\ \text{raised}_1 \\ \text{served} \\ \vdots \end{matrix}\right\}$

PR2: $x + y \longleftrightarrow y + \left\{\begin{matrix} \text{appear}_1 \\ \text{run}_1 \\ \text{leave}_1 \\ \vdots \end{matrix}\right\} + \left\{\begin{matrix} \text{in}_1 \\ \text{at}_1 \\ \vdots \end{matrix}\right\} + X$

PR3: $x + y \longleftrightarrow y + \left\{\begin{matrix} \text{worth}_1 \\ \text{cost}_1 \\ \vdots \end{matrix}\right\} + x$

PR4: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{made}_1\\ \text{prepared}_1\\ \vdots\end{matrix}\right\} + \text{in}_2 + x + \left\{\begin{matrix}\text{style}_1\\ \vdots\end{matrix}\right\}$

PR5: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{like}_1\\ \vdots\end{matrix}\right\} + x$

PR6: $x + y \longleftrightarrow y + \left\{\begin{matrix}\emptyset\\ \text{to be}\end{matrix}\right\} + \left\{\begin{matrix}\text{made}_1\\ \text{produced}_1\\ \vdots\end{matrix}\right\} + \text{by}_1 + x$

PR7: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{made of}_1\\ \vdots\end{matrix}\right\} + x$

PR8: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{for}_1\\ \text{used}_1 + \text{for}_1\\ \vdots\end{matrix}\right\} + \left\{\begin{matrix}\emptyset\\ \text{hold}_1\\ \text{keep}_1\\ \text{detect}_1\\ \vdots\end{matrix}\right\} + x$

PR9: $x + y \longleftrightarrow y + \{\text{to be}_1\} + \left\{\begin{matrix}\text{used}_1\\ \vdots\end{matrix}\right\} + \text{by}_1 + x$

PR10: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{to be}_1 + \{\text{possessed}_1\} + \text{by}_1\\ \text{belong to}_1\\ \vdots\end{matrix}\right\} + x$

PR11: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{installed}_1\\ \text{produced}_1\\ \text{found}_1\\ \vdots\end{matrix}\right\} + \left\{\begin{matrix}\text{in}_3\\ \text{at}_2\\ \vdots\end{matrix}\right\} + x$

PR12: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{of}_1\\ \vdots\end{matrix}\right\} + x$

PR13: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{with}_1\\ \vdots\end{matrix}\right\} + x$

PR14: $x + y \longleftrightarrow y + \left\{\begin{matrix}\text{of}_2\\ \vdots\end{matrix}\right\} + x$

PR15: $x + y \longleftrightarrow x + \left\{ \begin{matrix} \text{in}_3\text{+which}_1 \\ \text{where}_1 \\ \vdots \end{matrix} \right\} + y + \text{to be}_1 + \left\{ \begin{matrix} \text{performed}_1 \\ \text{given}_1 \\ \text{taught}_1 \\ \vdots \end{matrix} \right\}$

PR16: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{concerning}_1 \\ \vdots \end{matrix} \right\} + x$

PR17: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{in}_3 \\ \vdots \end{matrix} \right\} + x$

PR18: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{caused}_1 \\ \vdots \end{matrix} \right\} + \text{by}_1 + x$

PR19: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{fought}_1 \\ \text{lead}_1 \\ \text{launched}_1 \\ \text{designed}_1 \\ \vdots \end{matrix} \right\} + \text{by}_1 + x$

PR20: $x + y \longleftrightarrow y + \text{in}_3\text{+which}_1 + x + \text{to be}_1 + \left\{ \begin{matrix} \text{served}_1 \\ \text{used}_1 \\ \text{played}_1 \\ \vdots \end{matrix} \right\}$

PR21: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{in}_1 \\ \vdots \end{matrix} \right\} + x$

PR22: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{in}_4 \\ \vdots \end{matrix} \right\} + x$

PR23: $x + y \longleftrightarrow y + \left\{ \begin{matrix} \text{against}_1 \\ \vdots \end{matrix} \right\} + x$

PR24: $x + (\text{object}_1\text{+which}_1\text{+y}) \longleftrightarrow (\text{object}_1\text{+which}_1\text{+y}) + x$

In the rules shown above, x and y stand for two distinct senses of words. The senses in the brackets of each rule specify some contexts. If any two senses x and y can legitimately occur in any of the contexts, the reading 'x + y' has the interactive meaning represented by the rule. For example, PR7 represents the interactive meaning which is the meaning relation between materials and physical objects. It essentially specifies the following condition: PR7 is applicable to any pair of proper senses x and y (i.e., x and y are the proper senses of words selected by the sense selection rule), if x and y fit in the context (_____ made of$_1$ _____). Or it is equivalent to say, PR7 is applicable to any pair of proper senses x and y if x has the conceptual properties of being something of which things are composed and y has the conceptual properties of being something which is composed of something. Any paraphrasing rule which is applicable to a reading of an expression represents the interactive meaning of the expression.

The senses in the bracket of each paraphrasing rule are alternative senses each of which forms a paraphrasing pattern with x and y . The paraphrasing patterns formed by the alternative senses specify the same interactive meaning. Any sense of a word which can be used to specify the meaning relation of senses, i.e., the interactive meaning represented by the rule, can be added to the list. The paraphrasing rules shown above do not contain all the paraphrasing patterns of the data listed in the preceding section. However, any new paraphrasing pattern can be added to the right-hand side of a rule without changing the function of the rule.

Paraphrasing rules which operate on senses of words are more general than ones which operate on words, since each sense can be realized by a multitude of words. In generating the paraphrases of expressions, the senses in the paraphrasing rules can be replaced by the words which realize them to form different paraphrases. For example, 'made of$_1$' in PR7 can be realized by 'made of', 'composed of', 'constructed of', etc. PR7 is applicable to the reading of 'concrete building'. By applying PR7, 'concrete building' can be transformed into many paraphrases such as 'building made of concrete', 'building composed of concrete', and 'building constructed of concrete'. Thus, each paraphrasing rule not only represents the common interactive meaning of many expressions, but also specifies the paraphrasing relation among many expressions.

In the paraphrasing rules, the subscripts of words specify the senses of words. PR24 represents the interactive meaning which is the relation between the object of an action and the actor, such as the interactive meaning in 'water cooler', 'money changer', etc. The senses of 'cooler' and 'changer' are equivalent to 'object$_1$ which$_1$ cool$_1$' and 'object$_1$ which$_1$ change$_1$'. PR24 essentially re-arranges the senses.

3.5 Procedures for Determining Interactive Meanings

Each paraphrasing rule in Section 4) represents an interactive meaning of a category of expressions shown in Section 3). To determine the interactive meaning of an expression, we search the paraphrasing rules to select the

one (more than one, if the expression has more than one interactive meaning) which is applicable to the reading of the expression. By applying the selected rule, we obtain the paraphrase which shows the interactive meaning of the expression. Given an expression E, the procedure to determine its interactive meaning(s) and to generate its paraphrases is as follows.

(a) Select the proper senses of the constituents of E by the sense selection rule shown in the previous section. E is an expression composed of a noun-adjunct and a noun. The contextual restriction of each sense realized by the noun specifies in terms of concept-classes, the conceptual properties of the senses of its modifiers. The sense selection rule selects those sense(s) of the noun-adjunct whose concept-class(es) is either contained in the contextual restrictions of the senses of the noun or dominated by the concept-classes in the contextual restrictions. The reading E is formed by one sense of the noun-adjunct and one sense of the noun selected by the sense selection rule. If E is ambiguous, it will have more than one reading. Each reading of E would go through the following steps to determine its interactive meaning. For simplicity, I shall assume that E has a single reading Q_1.

(b) The reading Q_1 matches the left hand side of all paraphrasing rules since x and y in the rules are variables and stand for any senses of words. We want to find the rule(s) which is applicable to the reading Q_1. Applying all paraphrasing rules, i.e., substituting the senses in Q_1 for x and y in all rules, we obtain the transformed sequences of senses

$T_1\ T_2 \cdots\ T_n$ (n is the number of paraphrasing rules). Each T may contain more than one sequence of senses since each alternative sense in the bracket of a rule may form a distinct sequence with the senses in Q_1. By the sense selection rule, we may determine the compatibility of the senses in the sequences in $T_1\ T_2 \cdots\ T_n$. If the senses in any sequence in T_i, for some i in the range $1 \leq i \leq n$, are compatible to one another according to the sense selection rule, P_i is applicable to Q_1. Thus, the interactive meaning of E can be represented by P_i. In case more than one paraphrasing rule is applicable to Q_1, E has more than one interactive meaning.

(c) The senses of the sequence in any T_i found in the preceding step can be replaced by the words which realize them to obtain the paraphrases of E. The paraphrases may not be grammatical, however, they have roughly the same meaning contents as E.

Let us work through an example by following the proposed procedure. Suppose, the given expression is 'paper plate'. In step (a), we check the contextual restrictions in the lexical entries of the senses of 'plate' to find the sense(s) which is compatible with the sense(s) of 'paper'. Since 'paper' is a proper modifier of 'plate', the sense selection rule will select '$paper_1$' and '$plate_1$' as the proper senses. "$Paper_1$' and '$plate_1$' stand for the most common senses of 'paper' and 'plate' respectively.

In step (b), we find that '$paper_1$ + $plate_1$' matches with the left-hand side of all the paraphrasing rules. The rules are applied to obtain such se-

quences of senses as 'plate$_1$ + in$_3$ + which$_1$ + paper$_1$ + to be$_1$ + sold$_1$'; 'plate$_1$ + in$_3$ + which$_1$ + paper$_1$ + to be$_1$ + produced$_1$'; 'plate$_1$ + in$_3$ + which$_1$ + paper$_1$ + to be$_1$ + raised$_1$'; 'plate$_1$ + in$_3$ + which$_1$ + paper$_1$ + to be$_1$ + served$_1$'; 'plate$_1$ + appear$_1$ + in$_1$ + paper$_1$', etc. Using the sense selection rules to check these sequences of senses, we would find that the senses in some sequences are not compatible with one another. For example, 'plate$_1$' and 'in$_3$' (in$_3$ is the sense of 'in' realized in such expressions as 'in city', 'in Wisconsin', 'in store', etc. The sense specifies a regional location) in the first sequence are not compatible since the contextual restriction for the object or 'in$_3$' would not contain or dominate a concept-class to which 'plate$_1$' belongs. The sense selection rule would mark 'plate$_1$ + in$_3$ + which$_1$ + paper$_1$ + to be$_1$ + sold$_1$' as an anomalous reading. Applying the sense selection rule on each transformed sequence, we would find that the senses in 'plate$_1$ + made of$_1$ + paper$_1$' are compatible. Thus, PR7 in Section (5) is applicable to 'paper$_1$ + plate$_1$' and the interactive meaning of 'paper plate' can be identified by it.

In step (c), words which realize the senses 'plate$_1$', 'paper$_1$' and 'made of$_1$' can be substituted for the senses to form the paraphrases of 'paper plate'. For example, 'plate made of paper', 'plate composed of paper' and 'plate constructed of paper', can be paraphrases of 'paper plate' if 'made of', 'composed of' and 'constructed of' are judged by the language users to have the same sense 'made of$_1$'.

If the interactive meaning of an expression is ambiguous, there will be more than one paraphrasing rule selected in Step (b). Suppose 'glass container' is the given expression. Following the procedure, we will find that both PR7 and PR8 in Section (5) are applicable. This is because '$container_1$ + for_1 + $holding_1$ + $glass_1$' and '$container_1$ + $made\ of_1$ + $glass_1$' are all compatible. Thus, the multiple interactive meanings of an expression can be specified by the number of paraphrasing rules applicable to the reading(s) of the expression.

The meaning of an expression is represented by its reading and its interactive meaning(s) which in turn is represented by the paraphrasing rule(s) applicable to the reading. The meaning of 'paper plate' can be represented by PR7 ($paper_1$, $plate_1$) and the meaning of 'glass container' can be represented by PR7$\vee$PR8 ($glass_1$, $container_1$) where $\vee$ is the disjunction marker.

We can identify the paraphrasing relation of two expressions by checking the paraphrasing rules associated with them. If they are associated with the same rule and their readings match both sides of the rule, the expressions are paraphrases of each other. For instance, from the example above, we know that 'paper plate' has the meaning PR7 ($paper_1$, $plate_1$). The reading of 'plate made of paper' matches with the right hand side of PR7. Applying PR7 to transform the reading '$plate_1$ + $made\ of_1$ + $paper_1$' into '$paper_1$ + $plate_1$', we would find that '$paper_1$ + $plate_1$' is a well-formed reading according to the sense selection rule. Thus, PR7 is applicable to '$plate_1$ + $made\ of_1$ + $paper_1$' and the meaning of 'plate made of paper' can be repre-

sented as PR7 (plate$_1$, made of$_1$, paper$_1$). Since 'paper plate' and 'plate made of paper' associate with the same rule, and (paper$_1$, plate$_1$) and (plate$_1$, made of$_1$, paper$_1$) match both sides of PR7, they are paraphrases of each other. If two expressions are associated with the same paraphrasing rule, but their proper senses do not match with the sequences on both sides of the rule, the expressions have the same interactive meaning but are not paraphrases of each other. The meaning of 'iron bar' can be represented by PR7 (iron$_1$, bar$_1$). However, since (iron$_1$, bar$_1$) and (paper$_1$, plate$_1$) do not fit both sides of PR7, 'iron bar' and 'paper plate' are not paraphrases even though they have the same interactive meaning.

Expressions whose proper senses match with the right hand side of the paraphrasing rules can not always be transformed into the left-hand side of the rule, i.e., the resulting sequence of senses may not be compatible with one another. Let us take a category 'occupation' for illustration. This category contains such expressions as 'fish man', 'newspaper boy', 'egg lady', 'garbage man', 'house lady', 'milk man', 'mail man', and 'horse doctor'. The paraphrasing rule for this category is:

$$\text{PRX:} \quad x + y \longleftrightarrow \text{who}_1 + \left\{ \begin{matrix} \text{sell}_1 \\ \text{deliver}_1 \\ \text{collect}_1 \\ \text{treat}_1 \\ \vdots \end{matrix} \right\} + x$$

An expression <u>man delivers paintings</u> is a meaningful one. The proper senses of the constituents of this expression match with the sequence of senses on the right-hand side of PRX. Applying PRX, we will obtain the sequence of

senses 'painting$_1$ + man$_1$'. However, the senses are not compatible since 'painting man' is not a legitimate expression and thus the contextual restriction of 'man$_1$' would not contain or dominate the concept-class to which the sense(s) of 'painting' belongs. Consequently, PRX is not applicable to the reading of 'man delivers paintings'. Thus, 'man delivers paintings' does not have 'painting man' as its paraphrase.

There is one complication in the generation of paraphrases which is caused by the alternative senses in the brackets of the paraphrasing rules. Suppose a and b is a pair of senses compatible with one another. We may apply a paraphrasing rule to transform a + b into sequences of senses, each of which is formed by the senses a and b and one of the alternative senses in the bracket on the right hand side of the rule. In some cases, the senses of more than one of these sequences are compatible with one another. However, not all these sequences whose senses are compatible with one another can be used to generate the paraphrases of a + b. For example, 'horse doctor' is a legitimate expression. The proper senses of its constituents, 'horse$_1$' and 'doctor$_1$', match with the left hand side of PRX. Applying PRX, we would obtain the readings 'doctor$_1$ + sell$_1$ + horse$_1$', 'doctor$_1$ + deliver$_1$ + horse$_1$', 'doctor$_1$ + collect$_1$ + horse$_1$', 'doctor$_1$' + treat$_1$ + horse$_1$', etc. due to the list of alternative senses in the bracket of PRX. The senses in the readings, except in 'doctor$_1$ + collect$_1$ + horse$_1$', are all compatible with one another. However, they cannot all be used to generate the paraphrases of 'horse doctor' in step (c) since 'horse doctor' does not mean 'doctor sells horse' or 'doctor

delivers horse'. Only the reading 'doctor$_1$ + treat$_1$ + horse$_1$' can be used to generate the paraphrase of 'horse doctor'.

Therefore, if several readings result from the application of a paraphrasing rule we have to select one reading among them for generating the paraphrases. One solution to this is to assign a "marker of identifying function" to a concept-class in the contextual restrictions of each defined sense, if the concept-class contains senses which specify the identifying function of the defined sense or to which the defined sense is an identifying function. For example, 'treat$_1$', 'heal$_1$' and 'cure$_1$' specify the identifying functions of 'doctor$_1$' as opposed to the subsidiary functions specified by 'sell$_1$' and 'deliver$_1$' (deliver means to give out). Thus, in the contextual restrictions of 'treat$_1$' 'heal$_1$' and 'cure$_1$', we may assign a marker to the concept-class to which 'doctor$_1$' belongs. Since 'doctor$_1$' is a legitimate subject of 'sell$_1$' and 'deliver$_1$', 'doctor$_1$' would belong to a concept-class in the contextual restrictions of both 'sell$_1$' and 'deliver$_1$'. However, the concept-class would not be assigned with the "marker of identifying function" since 'sell$_1$' and 'deliver$_1$' do not specify the identifying functions of 'doctor$_1$'. In considering 'doctor$_1$ + sell$_1$ + horse$_1$', 'doctor$_1$ + deliver$_1$ + horse$_1$' and 'doctor$_1$ + treat$_1$ + horse$_1$' for the sequence of senses for generating the parahprases of 'horse doctor', we would select 'doctor$_1$ + treat$_1$ + horse$_1$' since 'treat$_1$' rather than 'sell$_1$' and 'deliver$_1$' specifies the identifying function of 'doctor$_1$'. Thus, the selection of the proper sequence of senses for generating paraphrases can be based on the marker assigned to the concept-class(es) in the contextual restrictions of the senses.

The assignment of the marker to the concept-classes in the contextual restrictions would rely on the language user's ability to distinguish which are the identifying functions and which are the subsidiary functions of senses. The selection of the identifying functions can be achieved through similar procedures used for the analysis of the word senses.

4. IMPLICATIONS OF THE THEORY

The implications of the proposed solution for the problem of interactive meaning have theoretical significance since we can determine what types of rules should be included in a semantic theory on the basis of what is necessary to account for the problem. Katz and his associates proposed that the projection rules form a component of a semantic theory. However, from a consideration of interactive meaning in noun-adjunct+noun constructions, we can see that taking the combination of readings of constituents as the derived meaning of a new constituent does not account for the meaning relation of the constituents. The meaning of the new constituent should be represented not only by the combination or sum of the readings of its constituents, but also its interactive meaning. The projection rules of the type proposed by Katz and his associates are not adequate since they do not account for the interactive meanings of the constituents.

We can construct paraphrasing rules of the type proposed to represent the interactive meanings existing in the constituents in the language. Given a reading of a constituent, we may select the paraphrasing rule(s) applicable to the reading. The paraphrasing rule(s), stands for the interactive meaning(s) of the constituent. Let us call the rule, which selects the paraphrasing rule(s) applicable to a given reading, the "interactive meaning selection rule". Step (b) of the procedure described in Section (3.5) is the interactive meaning selection rule for the noun-adjunct+noun construction. We may generalize it to obtain the following rule.

Rule: Given a reading E , and paraphrasing rules of the form $Q_1 \longleftrightarrow Q_2$ where Q_1 and Q_2 are readings or sets of alternative readings having the same interactive meaning, then paraphrasing rule is applicable to E , if E matches with a reading on one side of the rule and the application of the rule results in a semantically well-formed reading according to the sense selection rule.

Thus, the sense selection rule described in the previous section selects the proper senses of words in a constituent (here "constituent" refers to any linguistic unit larger than a word) and the interactive meaning selection rule above selects the proper paraphrasing rule(s) which represents the interactive meaning of the constituent. Together they form a component of a semantic theory.

The proposed solution to the problem of interactive meaning in noun-adjunct +noun constructions indicates that, for a semantic model to handle interactive meaning, the amount of the "real world" necessary to be included in the model depends on the number of distinct interactive meanings in the language. The determination of the interactive meaning(s) of an expression has been defined as the selection of the paraphrasing rule(s) applicable to the senses of the expression. In checking the applicability of a paraphrasing rule, we make use of the contextual restrictions of the senses specified in the paraphrasing rule. It was shown that the contextual restrictions actually specify a large amount of semantic information. Thus, the determination of which paraphrasing rules are and which are not applicable to the senses of an expression is based on our knowledge of a large amount of semantic information.

As the analysis of the expressions in noun-adjunct+noun constructions strongly indicates, the number of distinct interactive meanings in these constructions is limited. If the number of interactive meanings in other grammatical constructions is also restricted, paraphrasing rules of the proposed type can be constructed to represent the interactive meanings. To determine the interactive meaning(s) of an expression, we may search for the rule(s) which contains senses compatible with the proper senses of the expression. To do this, it is necessary that the contextual restrictions of both a) the senses specified in the paraphrasing rules and b) the proper senses of the expressions whose interactive meanings we want to determine, contain all concept-classes expressions whose interactive meaning we want to determine which can legitimately be combined with the concept-classes to which the senses belong. In order words, we need a 'full specification" of the contextual restrictions of both the senses in the paraphrasing rules and the senses of the expressions whose interactive meanings we want to determine. Under this condition, we can always determine whether or not a paraphrasing rule is applicable to an expression by checking whether the senses of the expression are compatible with the sense(s) specified in the rule. Thus, the amount of "the real world" necessary to be included in a semantic model is the amount of semantic information implicitly specified in the "full specification" of the contextual restrictions.

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